Indian Institute Of Technology Kanpur

AE 451A

Experiments in Aerospace Engineering-III

2021-22

Semester I

Experiment No. 1
Impact test to measure fracture energy of materials

Submitted By:

Ankit Lakhiwal

180102

(ankitl@iitk.ac.in)

Department of Aerospace Engineering

August 2, 2021

1. Objective

To determines the amount of energy absorbed by a material during fracture by evaluating its notch toughness.

2. Introduction and Theory

An impact test is used to observe the mechanics that material will exhibit when it experiences a shock loading that causes the specimen to immediately deform, fracture or rupture completely. The purpose of an impact test is to determine the ability of the material to absorb energy during a collision. This energy may be used to determine the toughness, impact strength, fracture resistance, impact resistance, or fracture resistance of the material depending on the test that was performed and the characteristic that is to be determined. These values are important for the selection of materials that will be used in applications that require the material to undergo very rapid loading processes such as in vehicular collisions.

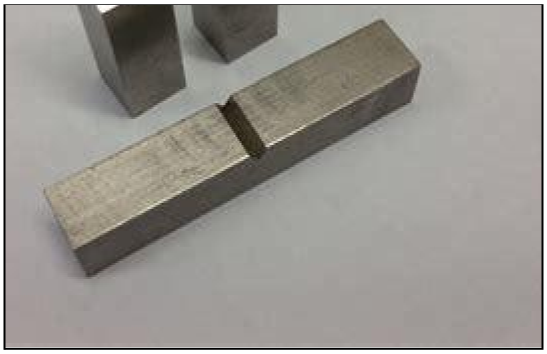
Here are some formulae that we will use to determine the Velocity and Displacement of the Impactor.

$$v(t) = v_i + gt - \int_0^t \frac{F(t)}{m} dt \tag{1}$$

$$\delta(t) = \delta_i + v_i t + \frac{gt^2}{2} - \int_0^t \left(\int_0^t \frac{F(t)}{m} dt \right) dt \tag{2}$$

3. Equipment's

a. Aluminum Charpy V-Notch Specimen



b. INSTRON CEAST 9340 drop weight impactor

The image shown here is a drop tower impact system that contains different parts.

It has impactor tup assembly. The first part is the tup die, and the second is the load cell which calculates the total force applied to the specimen during impact.

The top part of this machine is called a motorized crosshead positioning system which allows the impactor to free fall on the specimen from the specified height. It can go up to a maximum of 1.1m.

With maximum height and weight added to this system, we can achieve up to 4.65m/s maximum velocity and corresponding max. energy 405J.

This machine also has an anti-rebound system which allows it to prevent multiple hit to specimen

4. Procedure and Measurements

The following drawing is showing different zones of Charpy V-notch specimen:

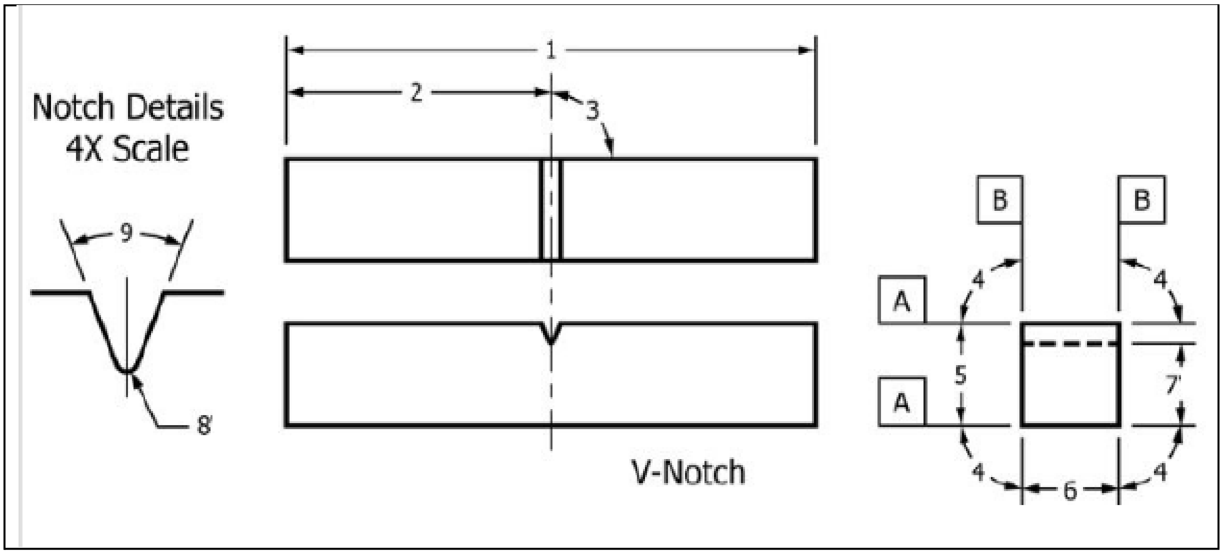


Table 1 Charpy V-notch specimen dimensions

S.N.	Description	Dimension	Tolerance
1	Length of specimen	55mm	$\pm\ 0.25mm$
2	Centering of notch	-	$\pm$1mm
3	Notch length to edge	90°	$\pm$2°
4	Adjacent side angle	90°	$\pm$0.17°
5	width	10mm	$\pm$0.075mm
6	Thickness	10mm	±0.075mm
7	Ligament Length	8mm	±0.025mm
8	Radius of Notch	0.25mm	±0.025mm
9	Angle of Notch	45°	±1°

The procedure to run the equipment and performing the experiment is given in the following.

a. Switch on the compressor and set the pressure to 6 bar
b. Power ON the Impactor equipment and press START at the control panel.
c. Place the pre-cracked specimen and align it with the loading tup.
d. At the control panel, go to Service option -> move to height -> change to H from Z.
e. Slowly move the tup downwards by using the control panel, until it just touches the specimen. Now set H = 0 on the control panel.
f. Adjust the photo-sensors location such that it gets activated before the impactor hits the specimen.
g. Open the CEAST software program on the computer and go to Process -> Parameters -> select appropriate ASTM standards.
h. Edit the test parameters in Process -> Parameters by providing appropriate values of the impactor mass, height / initial velocity/impact energy.
i. Go to Process -> Test execution -> Type in the operator name, test name etc.
j. In Process -> Parameters, choose ASTM E23 (for Charpy test).
k. Now press START on the computer. This moves the tup to its set height/position.
l. Press Continue to open the dialogue box. Click OK to begin the test.
m. Once the test is executed press END on the computer.
n. Go to Files on the computer interface, select the entered test name and extract the data. Save the raw data into an Excel sheet.

5. Calculation

Mass of the Impactor: 6.14 kg

Gravitational acceleration : 9.8 m/s^2

Initial Velocity of Load-Tup = 3.26 m/s

Acceleration : $a = g - F/m$

Velocity : $v = vi + g*t - \int F(t)dt$

Displacement : $d = di + vi*t + g*(t^2/2) - \iint F(t)dt$

6. Data Analysis

I. Experimental Data Table

	Pointn.	Time [s]	Displacement [m]	Energy [J]	Force [N]	Velocity [m/s]	Voltage Ch 1 [mV]
0	1	0.00000	0.000000	0.000	0.000	3.260	-0.407819
1	2	0.00001	0.000033	0.005	289.919	3.260	0.332516
2	3	0.00002	0.000065	0.022	791.908	3.259	1.614392
3	4	0.00003	0.000098	0.055	1225.444	3.258	2.721466
4	5	0.00004	0.000130	0.101	1578.447	3.255	3.622892
...	...	...	...	...	...	...	...
4565	4566	0.04565	0.128637	-32.178	-558.362	4.861	-1.833648
4566	4567	0.04566	0.128686	-32.205	-557.691	4.862	-1.831935
4567	4568	0.04567	0.128735	-32.232	-558.362	4.863	-1.833648
4568	4569	0.04568	0.128783	-32.259	-555.678	4.864	-1.826794
4569	4570	0.04569	0.128832	-32.287	-561.047	4.865	-1.840503

4570 rows × 7 columns

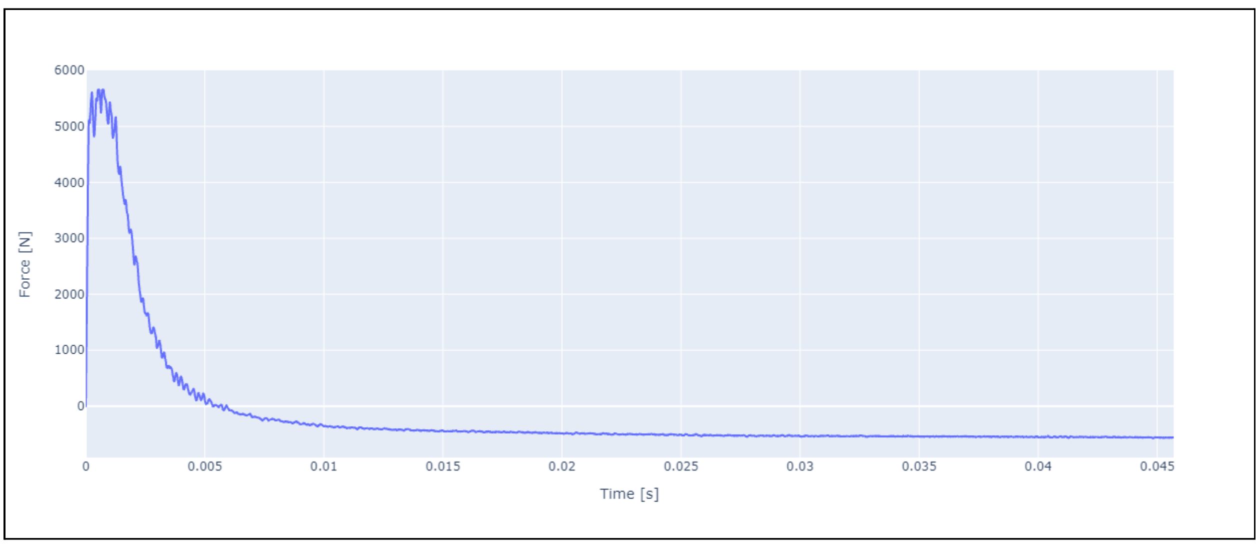
II. Theoretical Data Table

	Pointn.	Time [s]	Displacement_Th [m]	Energy_Th [J]	Force [N]	Velocity_Th [m/s]
0	1	0.00000	0.000000	0.000000	0.000	3.260000
1	2	0.00001	0.000033	0.004726	289.919	3.259862
2	3	0.00002	0.000065	0.022356	791.908	3.259079
3	4	0.00003	0.000098	0.055222	1225.444	3.257534
4	5	0.00004	0.000130	0.100876	1578.447	3.255349
...	...	...	...	...	...	...
4565	4566	0.04565	0.128646	-32.179176	-558.362	4.861424
4566	4567	0.04566	0.128694	-32.206307	-557.691	4.862431
4567	4568	0.04567	0.128743	-32.233443	-558.362	4.863438
4568	4569	0.04568	0.128792	-32.260536	-555.678	4.864444
4569	4570	0.04569	0.128840	-32.287700	-561.047	4.865451

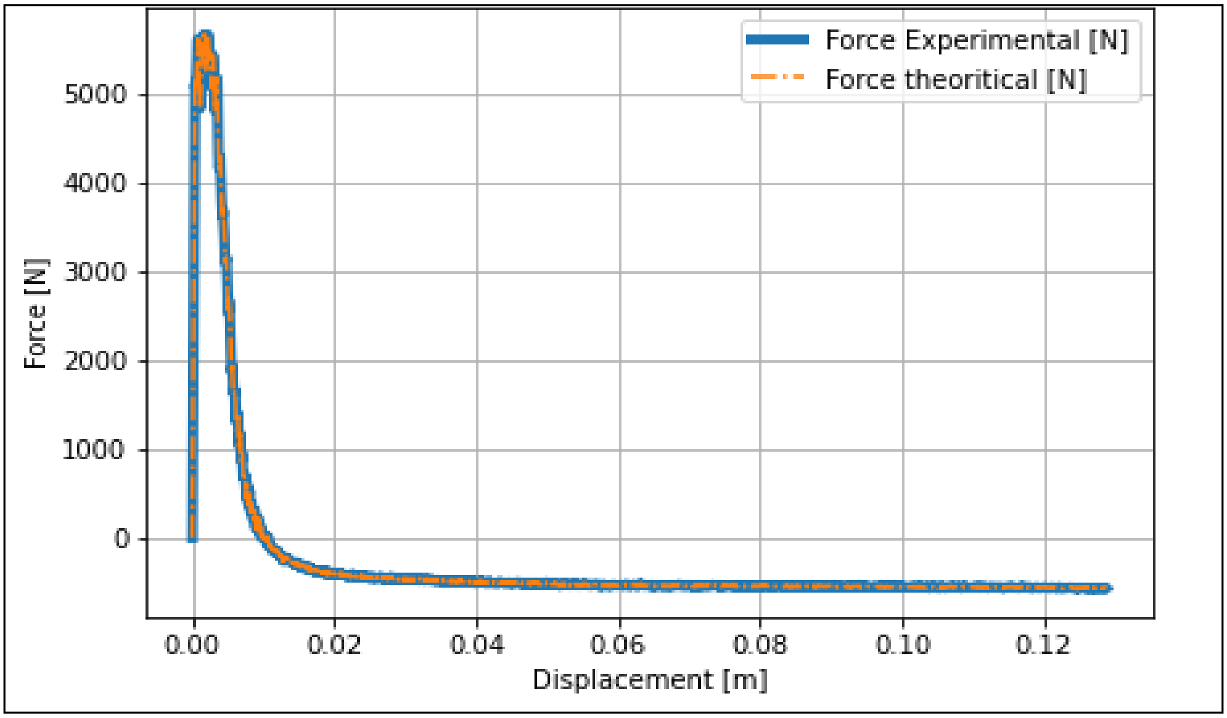
4570 rows × 6 columns

III. Data Visualization

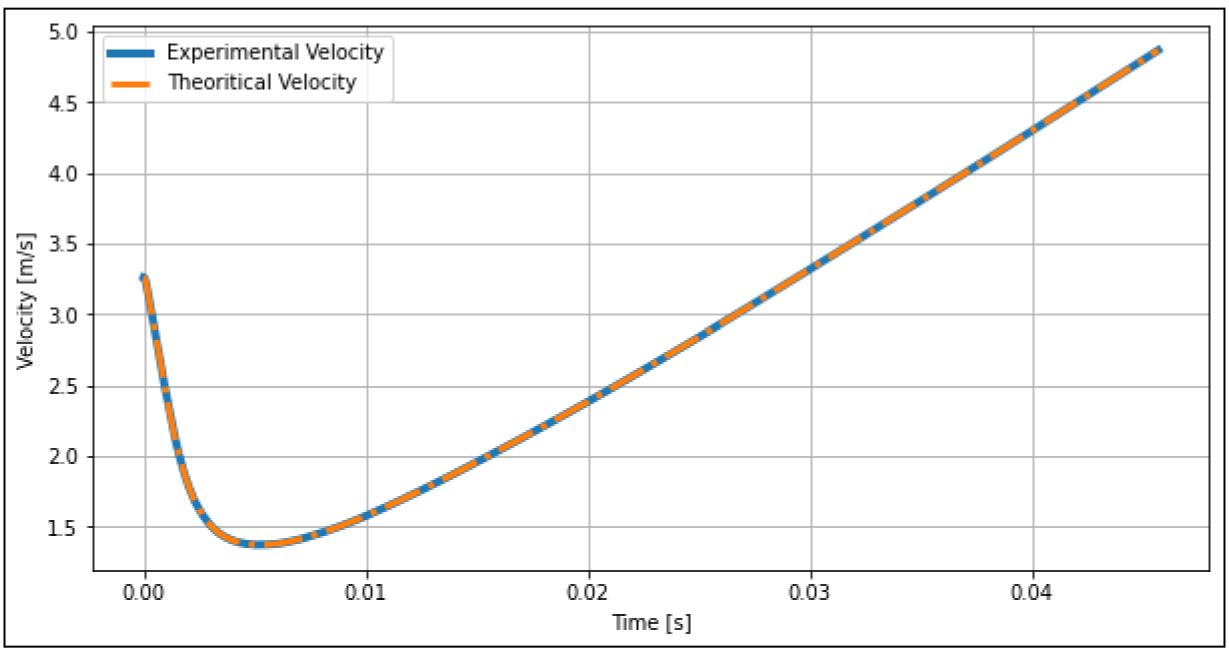
A. Force (N) vs Time(s)



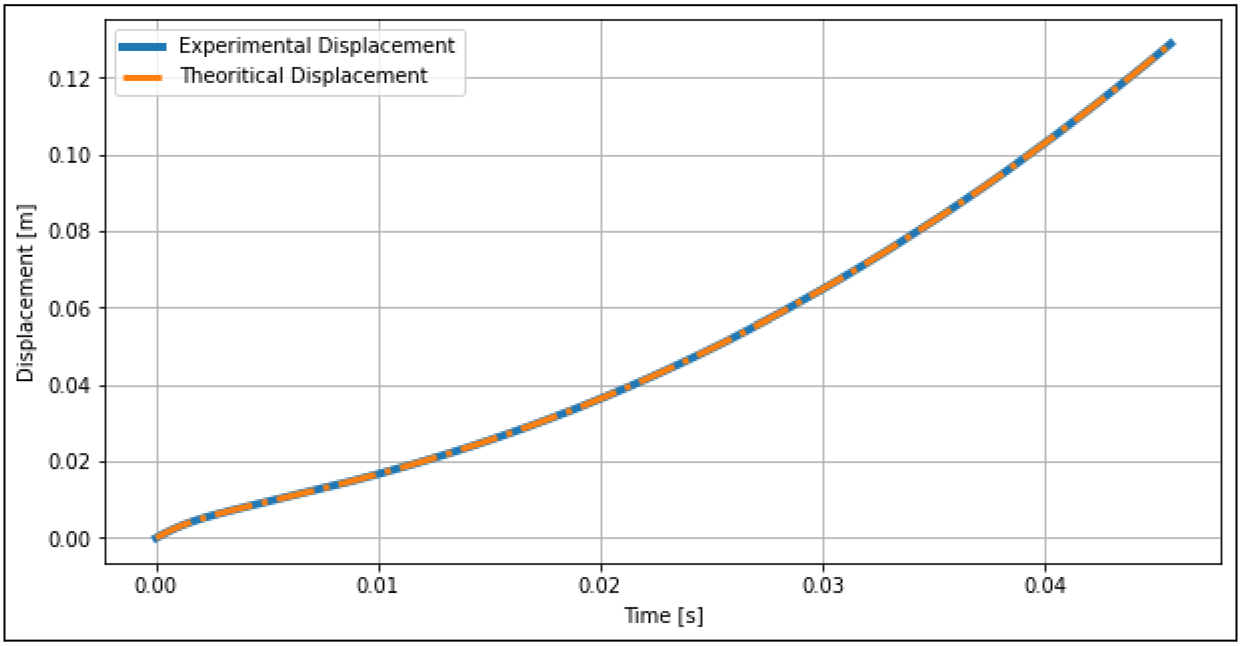
B. Force (N) vs Displacement (m)



C. Velocity (m/s) vs Time (s)

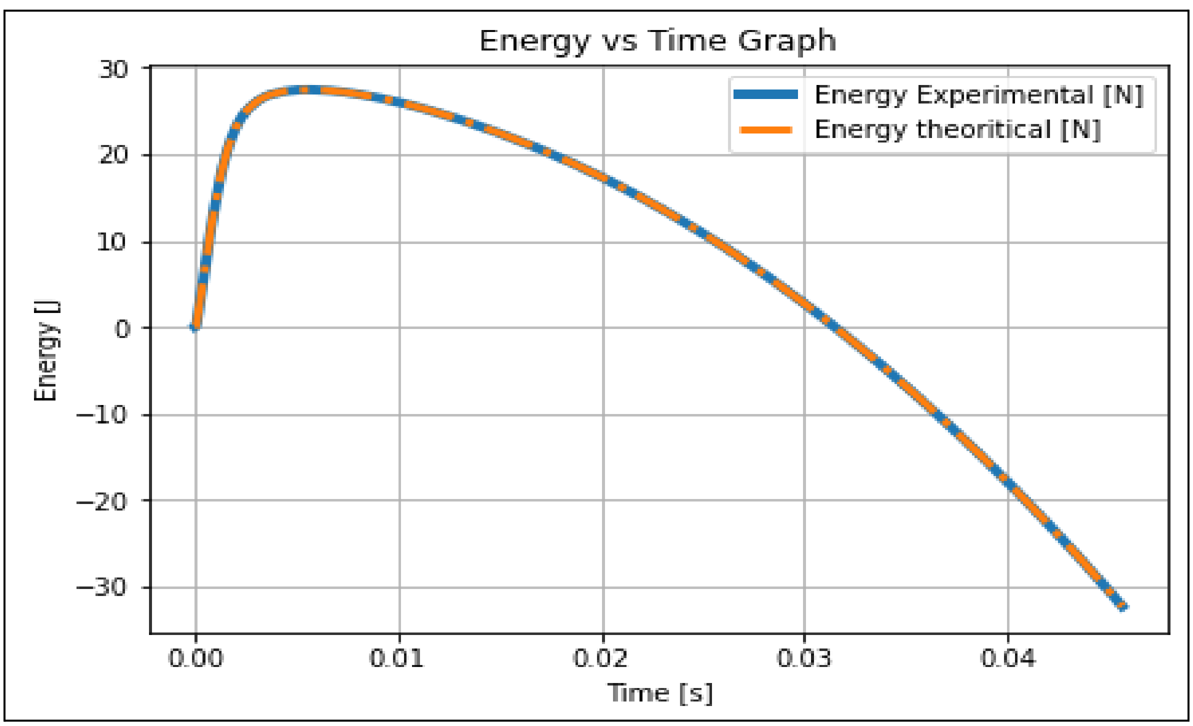


D. Displacement (m) vs Time (s)



E. Energy [J] vs Time [S]

Total Energy absorbed: -32.867 J

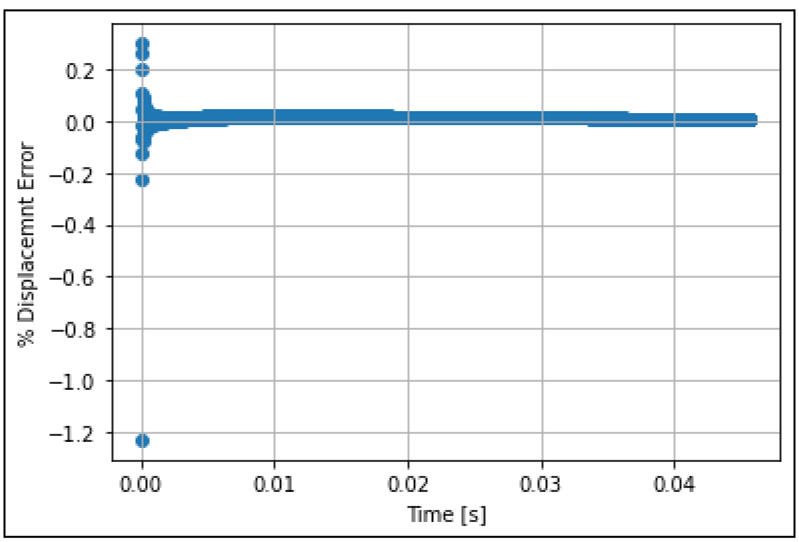


7. Error Analysis

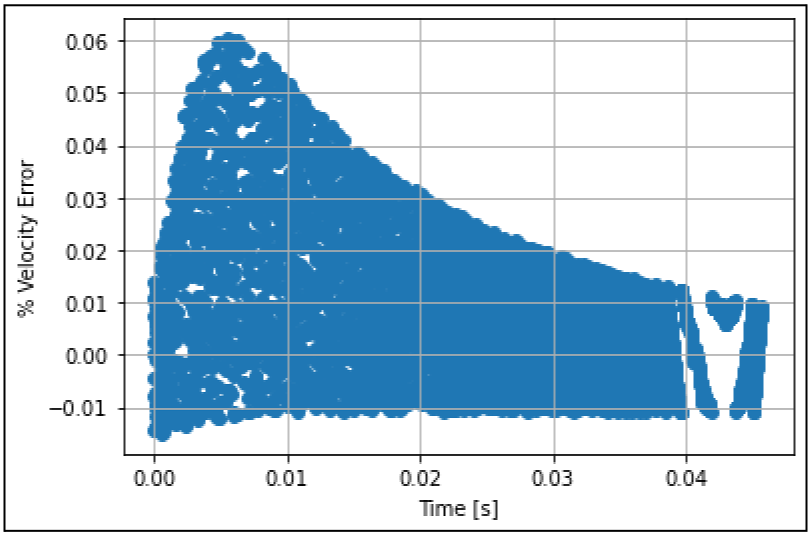
% Error = ((Theoretical_Data – Experimental_Data)/Theoretical_Data)*100

	% Displacement Error	% Velocity Error	% Energy Error
count	4569.000000	4570.000000	4569.000000
mean	0.012064	0.009422	0.002985
std	0.020770	0.014959	0.257417
min	-1.229136	-0.015060	-10.663790
25%	0.009186	-0.001841	0.001891
50%	0.012762	0.007061	0.004741
75%	0.015723	0.017336	0.006818
max	0.297598	0.060308	11.241514

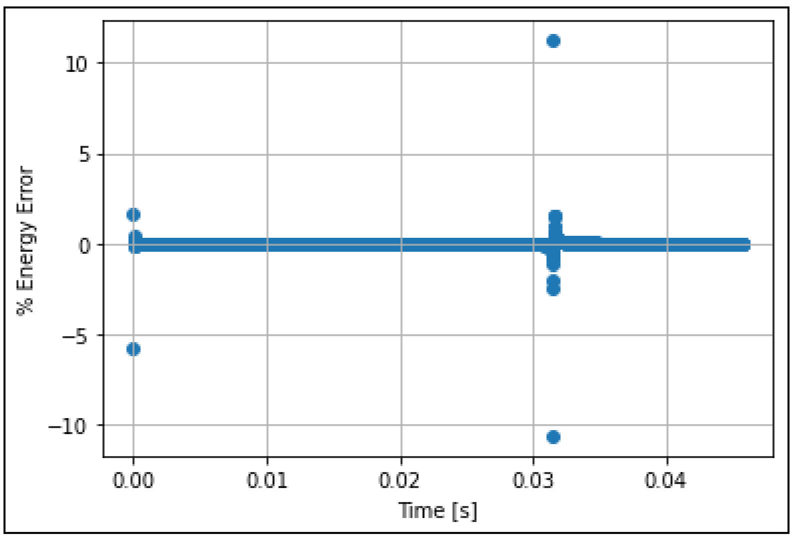
I. % Displacement Error vs Time [ms] graph



II. % Velocity Error vs Time [ms] graph



III. % Energy Error vs Time [ms] graph



8. Conclusion

a. The specimen's fractured surface was rough due to its ductile nature.

b. The graph for experimental and theoretical data are almost the same, which means computer software in the experiment used trapz function to calculate the different variables.

c. Error in Displacement and Velocity is high at initial state during impactor hit the specimen which can be seen in force vs time graph also.

d. There are four points in the energy error graph where the error is so high than mean error

9. References

Click on the link for detailed code:

Lab-1 Jupyter Notebook